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GEOLOGICAL PHOTOINTERPRETATION OF THE PARAGUANA PENINSULA USING ERTS-A MULTIESPECTRAL PHOTOGRAPHY

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ABSTRACT. The objetive of this study is the development of a methodology to evalua te multiespectral analysis of orbital imagery on the interpretation of geology, coastal geomorphology and sedimentary processes, in manners useful for Urban Regional Planning and in the evaluation of Natural Resources.

The images analyzed were obtained during the pass of ERTS satellite through the Center Region of Venezuela in October 19-1972, at 69°20' to 71° 00' long. W and 10° 45' to 12° 15' lat. N. (Paraguaná Península) ERTS-A multiespectral images in black and white paper copies and transparencies of the 4 bands and false color composites at scales of 1:1.000.000 and 1:500.000 were interpreted with the aid of a magnifiying glass and microfilm viewer.

Lithology and outcrop patterns of the following geological formations have been interpreted: igneous and metamorphic basement of Cocodite and Santa Ana, Jurassic-Cretaceous metamorphics of Pueblo Nuevo, Cantaure Miocene-Pliocene sediments, and Quaternary alluvium, dunes, beach ridges, bars and reefs. A prominent and extensive "Paraguaná" tonal anomaly" shaped as an 8 has been discovered at the NW of the Península. Its erosional origin has exposed light toned lower beds at the center, with additional evidence of topographic depression and development of underground drainage of karst origin.

The Península structure is a plateau with near horizontal beds, with two gentle domes culminating in the basement cores of Cocodite and Santa Ana, with the E-W trending Buena Vista syncline in between; all the folding due to sedimentary dip and diferential compaction. The Punta Salinas normal fault, down thrown to the north, trends ENE-WSW for over 35 Km from the coast to Mesa de Cocodite. Other smaller fault systems are the NW-SE trending Punta Macolla, and the NNE-SSW Bahía de Amuay systems.

Coastal geomorphology, its processes and energy has been interpreted with the help of wind direction analysis (ENE-WSW) at sea level through the orientation of transported materials (water vapor, water and sediments) by clouds, waves, sea current, plumes of suspended sediments associated to river outlets, dunes, sediment sources and shore line orientation.

The Paraguaná coastline has been sectorized (according to its linearity, orientation and typical geoforms) as follows: the Southern coast, straight with gentle dip slopes and 3 sand bodies, the Eastern coast straight with a few beach ridge systems and embayments with barrier reefs, sand bars, lagoons and salt flats; the Northern coast, straight with few beach sediments and some dunes; and the Western coast with embayments and 2 sand spits.

Surface water bodies and drainage beds have been interpreted using soil pattern and vegetation of the gallery forest type.

For the current land usage, the following has been interpreted: cultivated plots and grazing lots on the rural areas around Adícora, Pueblo Nuevo, Buena Vista, Amuay, Cardón and Coro; the urban areas of Coro and Amuay-Cardón, and the industrial area refineries with details of oil tanks, their retaining walls and large sheds. Engineering works were also identified such a dams, airports, roads, oil pipes and a water pipe.

1. STRATIGRAPHY. Most important rock outcrops of pre-Tertiary age Igneous-Metamorphic basement are located in the Western sector of the Península, at the Santa Ana Hill (covered in the image by a well developed cumulus) and at the Cocodite Mesa. Both areas are observed in the 4 bands with dark grey tones and in the color composite (4, 5, 6) appear with dark to very dark grey due to their composition of white granitic rocks (quartz, white feldspar and mica) which reflect I.R.

Marine shallow water sedimentation took place during the Tertiary. Clay, sand and coral reefs developed around the nuclei of the basement. Tertiary Formations are observed as Mesas Slightly tilted. They cover the entire Península and originate a plain where light and dark grey tonal responses alternate according to the predominance of ground material (limestones, sandstone or clay and vegetation).

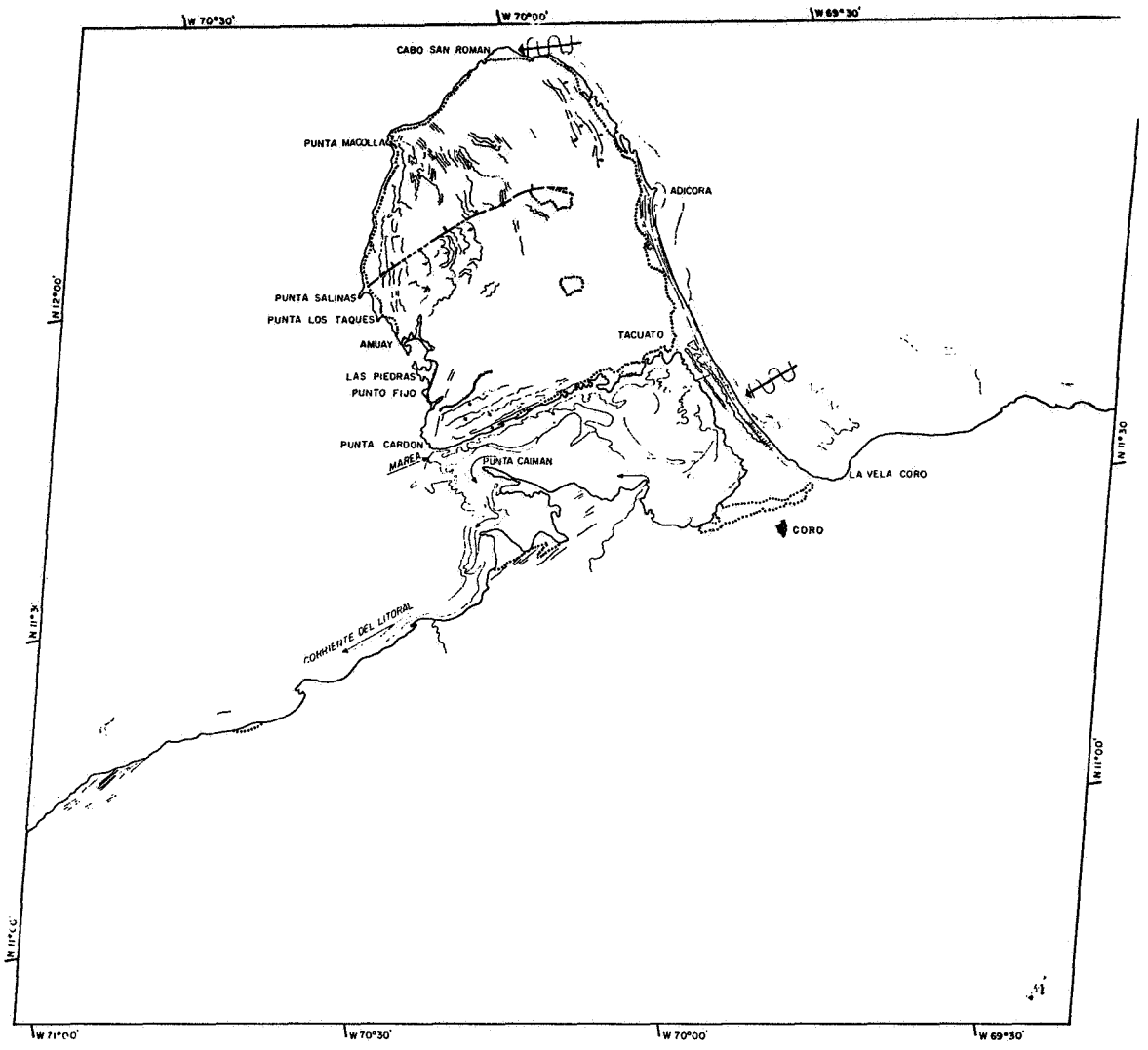
In the N.W. side of the Península, two circular tonal anomalies are observed in all 4 bands, as well as in the color composite. Light gray to white linears shape an 8 form on a medium gray base. These tonal anomalies are present in areas of erosion and removal of overlying -possibly Pliocene- strata of almost horizontal position, identified by medium gray tones. Erosion has discovered older strata -possibly Miocene- formed by limestone and sandstone, identified by white to light gray tones.

The origin of these anomalies, as well as that of the depression of Amuay Bay, could be karstic. Both circles of the 8 shape are separated by the Punta Salinas Fault. Existing maps at scale 1:1.000.000 show some topographic evidence for the northernmost circle as well as some surface drainage which disappear and may continue underground within the circle, at the place called Orejitas, S.W. of Macolla. The Southern circle is surrounded by important topographic evidence; within it there is a depression, W. of Jadacaquiva.

Geologic contact of Quaternary and Tertiary has been drawn with great detail. Quaternary forms a narrow strip of ligth to white gray tones which surround the Península. This strip has been formed by litoral sedimentation processes and in its composition predominate quartz sand. There exist dunes and some alluvial materials. Salt flats, barrier bars and coastal lagoons present an intermediate gray tone in all bands but in color composites (4, 5, 6) acquire a light blue color. Barrier reefs are distinguished in all 4 bands with medium gray tonal response with light gray tones at the border.

2. STRUCTURE. The Península appears at the borders as a Mesa with strata dipping almost horizontal. Al the center, regional structure resembles two soft domes which culminate at the nuclei of the basement and are seen as follows:

SIDE	SLOPE	SLOPE DIR.	OTHER
South	Gentle to Nil	South	---
East	Medium-Gentle	East	---
North	Gentle to Nil	North	Faulted
West	" to Nil	West	---


W 70°30'
W 70°00'
W 69°30'
CABO SAN ROMAN
PUNTA MACOLLAR
ADICORA
PUNTA SALINAS
PUNTA LOS TAQUES
AMUAY
TACUATO
LAS PIEDRAS
PUNTO FIJO
PUNTA CARDON
MAREA
PUNTA CAIMAN
LA VELA CORO
CORO
CORRIENTE DEL LITORAL
N 12°00'
N 11°30'
N 11°00'
W 71°00'
W 70°30'
W 70°00'
W 69°30'
CONTACTO GEOLOGICO
ESCARPADO
RUMBO Y BUZAMIENTO DE CAPAS
FALLA NORMAL
LINEACIONES
DIRECCION DEL VIENTO
DIRECCION DE LAS CORRIENTES MARINAS
PLUMA DE SEDIMENTOS EN SUSPENSION
Q ALUVION (A) DUNAS (D) CUATERNARIO
MPc FORM. CANTAURE PLIOCENO MIOCENO
JKpn FORM. PUEBLO NUEVO JURASICO CRETACEO
ROCAS IGNEAS PRE-JURASICAS
REGION DE LA PENINSULA DE PARAGUANA
GEOLOGIA Y GEOMORFOLOGIA
ELABORO C ALBRIZZIO
Kmts. 0 10 20 30 40 50
OCT. 1972 FOTOG. SATELITE ERTS-1 IDENT 1088-14300

Between both nuclei there is a gentle syncline trending E.W. the dome of Cocodite, the dome of Santa Ana and the syncline of Buena Vista form a system of folds with origin due to depositional dip and differential compaction over a basement with topographic relief.

There are numerous evidences of faulting, with faults grouped in systems. The Midwestern part of the Peninsula is cut by the Punta Salinas fault extends ENE-WSW for 35 Km from Punta Salinas to the N of Cocodite Mesa. This fault is detected in all 4 bands by: a) the topographic expression of the lineament; b) the displacement of the strata on the west coast and central plateau; c) the light gray tonal response of outcrops along river beds. Northern side of the fault has been relatively lowered.

At the northern side of the Peninsula, East of Punta Macolla, it is observed a NW-SE faults system 16 Km long which controls numerous creeks. these faults are evident by their linearity, by the drainage or by the light gray tones of outcrops.

In the S.W., near the bay of Amuay, it is observed a system of faults extending NNW-SSE for 5 Km, faults are evident along the Jayana creek, at the cliffs and by their topographic expression.

3. LITORAL DYNAMICS. Accumulation of sediments is controlled by winds, wind direction, river discharge, long shore drift and by the energy balance of rivers and the sea.* The rivers of the region do not penetrate long within the sea, and this fact indicates that sea energy controls the distribution of sediments along the shoreline. The di-

* Wind is the most important energy element intervening in the formation of waves and ocean currents. Both waves and ocean current as well as fluviatil currents are the most important components of litoral dynamics. Wind direction was determined at different places and altitudes by interpreting directional movement of the elements transported

rection of Eastern wind is constant along the coastal region. Sea current is the variable which controls the distribution of sediments.

Both at the Eastern coast of the Península and of the Istmo, shorelinesare oriented NW-SE, almost normal to wind direction and offers a barrier to the transport of sediments by the sea current. The wind diminishes its energy and local deposition takes place giving way to wide strips of sediments along the shoreline which is redistributed by longshore drift. Part of those sediments are transported by wind to form different types of dunes inland. **

The N and NE coast of the Peninsula are oriented from E-W. to NE-SW, almost parallel to wind direction. As they do not offer great resistance to sediment transportation, they only accumulate narrow strips of litoral and eolic sediments.

The West coast is oriented NW-SE and has little accumulations for it is protected from sea current by the Península. At the West coast of the istmo, eolic and fine marine sediments are being accumulated, the latter being carried by the current of the Golfete de Coro.

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*... (water, water vapor and sediments). At sea level, waves, long shore drift and eolic sediment patterns were used as evidence. At other altitudes, patterns of clouds were used as evidence. The elongation of eolic geoforms indicate a persistent regional direction of wind ENE to WSW at sea level.

** Accumulation of dunes are encountered at the following places:
- Istmo de Médanos: extensive and frequent longitudinal dunes.
- Cape San Román and Punta Macolla:longitudinal dunes.
- Médanos de Coro: abundant and well developed transversal dunes.
- Llano de Chenguito: interpreted as an accumulation of sand. Possibly transversal dunes not verified by field work.
- Delta del Río Mitare: cevered with longitudinal dunes.

The direction of waves and its refraction are not visible in the images at the scale of 1:500.000, but litoral dynamics is evident by plumes of densely suspended sediments that are observed associated with river outlets. Directional elongation of plumes indicate their transport direction as well as the direction of the long shore drift.

The general direction of the marine current is ENE-WSW as indicated by wind direction and by the pattern of the lower level of clouds. The direction of the long shore dfif is indicated by the direction of plumes. Sediments plumes are observed in the following places:

- Punta Manzanillo (from Puerto Cumarebo to Ricoa river). Sediments from this river form 3 plumes extended towards the N.W. which dissappear at the Bahía de la Vela where aparently sedimentation takes place. The longest plume is 4 Km long and the others are 1 Km long each one. Along side and continuing the largest plume, there can be observed a tonal anomaly that can be interpreted is a plume although it could be the shadow of a cirrus.
- Punta Taimataima to La Vela de Coro. There can be observed a narrow strip of 4 lobuli extended towards the NW. One of the plumes reaches the Istmo de Médanos where sedimentation accurs.
- Vela de Coro to East coast. a narrow strip of suspended sediments from river Coro is observed.
- Golfete de Coro. Its waters are rather shallow, with mean depth of 6 m. and with a narrow channel 8 m. depth. River Mitare's sediments are constantly filling the golfete. It is evident that the delta has been progressively displaced to the E. Ahead of the river Mitare Delta, it can be observed a dense plume of suspended sediments with numerous

lobuli displaced counter clockwise along the shoreline. Other minor plumes are displaced C.C.W. towards the E. of the golfete, creating thus a C.C.W circulation cell in the midpart of the golfete.

River Mitare's plume has irregularities of anomalous forms. They have been interpreted as the affect of friction among the sediments and clean seawater that is carried Eastwards.

At the west coast of the Golfete there is a narrow strip of suspended sediments from the rivers Codore, Mitare, Zazárida, Capatárida and Borojó. The plumes are displaced WSW following the litoral current and deposit their sediments along this coast.

4. LITORAL MORPHOLOGY. The coast line of the Península has been sectorized according to orientation of shoreline and predominant geoforms:

a. SOUTHERN COAST. Extends from Punta Cardon to Tacuato, oriented NNE except at the eastern extreme where it is interrupted by 3 accumulations. Geologic contacts between Holecene sediments and interestratified Miocene-Pliocene rocks can be observed through tonal changes from white to light yellow to dark yellow in the false color composite. This coast is controlled NNE and by the dip angle SSE of the strata that crop out. There have been recognized 12 paralell bands where dark gray tones (clay) alternate with light gray tones (limestone and sand).

At the West part of this coast sedimentation and sea energy are at equilibria. At the East part, there can be observed 3 sand bars possibly old keys partly eroded.

b. EAST COAST. The east coast (Tacuato to cape San Román) is strigh trends SSE-NNW. The Istmo de Médanos with similar features is also included here. The coast line is divided in the following sections after their geomorphic characteristics:

La Vela de Coro-Adícora coast line is 70 Km long and show a gentle curvature with a 200 Km. radius. The littoral zone is 3.5 to 5 Km wide and show predominantly beach ridges as alternate strips of white color (quartzose sands) with wider strips of pale gray tone (vegetation and higher moisture content on the low areas between ridges). Up - to 15 of them have been identified at a scale of 1:500.000 on band 5.

Three systems of beach ridges are found in this area:

- The oldest system extends intermitently for 15 km from Tacuato to halfway the istmo, where it is totally distroyed and covered by longitudinal dunes.

- The intermediate system extends for 15 km from Adícora to Tura (half way to Tacuato); it is 2 km wide and has a curvature radius of 10 km.

- The youngest system extend for 70 km from Adícora to La Vela de Coro, it is 1.5 km wide and has a curvature radius of 200 km.

The coast line north of Adícora has a general NNW-SSE trend, and show frequent - reentrants, associated with reefs, embayments and coastal lagoons. It has been divided in 3 areas:

- Adícora-San Pedro, of similar features to the area south of Adícora.

- San Pedro-Puerto Escondido, with barrier reefs, coastal lagoons and sand bars.

- Puerto Escondido-Cape San Román, of narrow beach and a 2 km wide belt of longitudinal dunes.

c. NORTH COAST. The north coast (Cape San Román to Punta Macolla) is a straigh NE-SW trending line with a gentle embayment NE of Punta Macolla. The rocks outcrop extend to the beach, except for the narrow belt of longitudinal dunes of Punta El Infierno.

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d. WEST COAST. The west coast (Punta Macolla to Punta Cardón) characteristically-lacks sediments, and has been divided in the following 4 parts according to their geomorphic features:

- Punta Macolla to Punta Salinas, a straight NNE-SSW trending coast controlled by - the beds and fractures that outcrop along the beach.

- Punta Salinas to Amuay Bay, with 2 embayments and sand spits (Punta Salina and Punta Los Taques) with their source being Las Tres Marías creek.

- Amuay Bay to Punto Fijo, with a series of embayments and points along the cliffs controlled by fractures. Although this area resembles a sunken coast, it lacks the suporting evidence for this origins, and a control by fractures and karstic origins is more likely.

- Punto Fijo to Punta Cardón, with a SW trend that charges to SE on the south, shows no cliffs, and a small salt flat.

Drainage.

Water bodies. The free surface of water bodies are better identified as black areas on band 7 of black and white photographs, due to the shallow penetration of IR radiations. On false color composition (bands 4,5 and 6) they are identified by a blue color, of a darkto pale tone, depending on an increasing amount of suspended sediments.

River beds and depressions. River beds, coastal lagoons, salt flats and dam reservoirs are better identified on bands 5 and 7 of black and white photographs.

On band 5, areas above water appear with a pale gray to white tone (Bajarigua salt pond, coastal lagoons north of Adícora, and rivers of Falcón). Some of these river beds of white tone appear with a dark gray to black background from their gallery forests.

On band 7, the river beds show dark gray to black in a pale gray background of their gallery forests.

Land usage.

The interpretation of land usage has been done according to the following types:

Rural areas. Small land plots are identifiable in the Península near Adícora, Pueblo Nuevo, Buena Vista, Amuay-Cardón and large plots west of Coro. These features are identified by their rectangular shape, of pale gray tones on a darker background, and are interpreted as agricultural land, grass fields and plowed land.

Urban areas. Coro and other smaller urban areas such as Amuay and Punta Cardón, Judacaquiva, etc are identified. These areas show a geometric outline of pale to medium gray on a darker background, with radial roads and dark cultivated vegetation.

Industrial areas. Tank farms, safety dikes and large sheds have been identified in the oil refineries of Punta Cardón and Amuay. On black and white photographs the tanks appear as black spots, framed by pale gray dikes, with their tones changing to yellow on false color compositions.

Engineering works. Water dams, roads, airports, oilpipes and water pipe and associated features are identified.

The El Isiro water dam is identified on band 7 by its free surface of water. El Cayude small dam is under clouds in the southern part of the península.

The roads are obvious in bands 4 and 5 as fine white to pale gray lines of geometric design in black and white photographs and pale yellow in false color composicions.

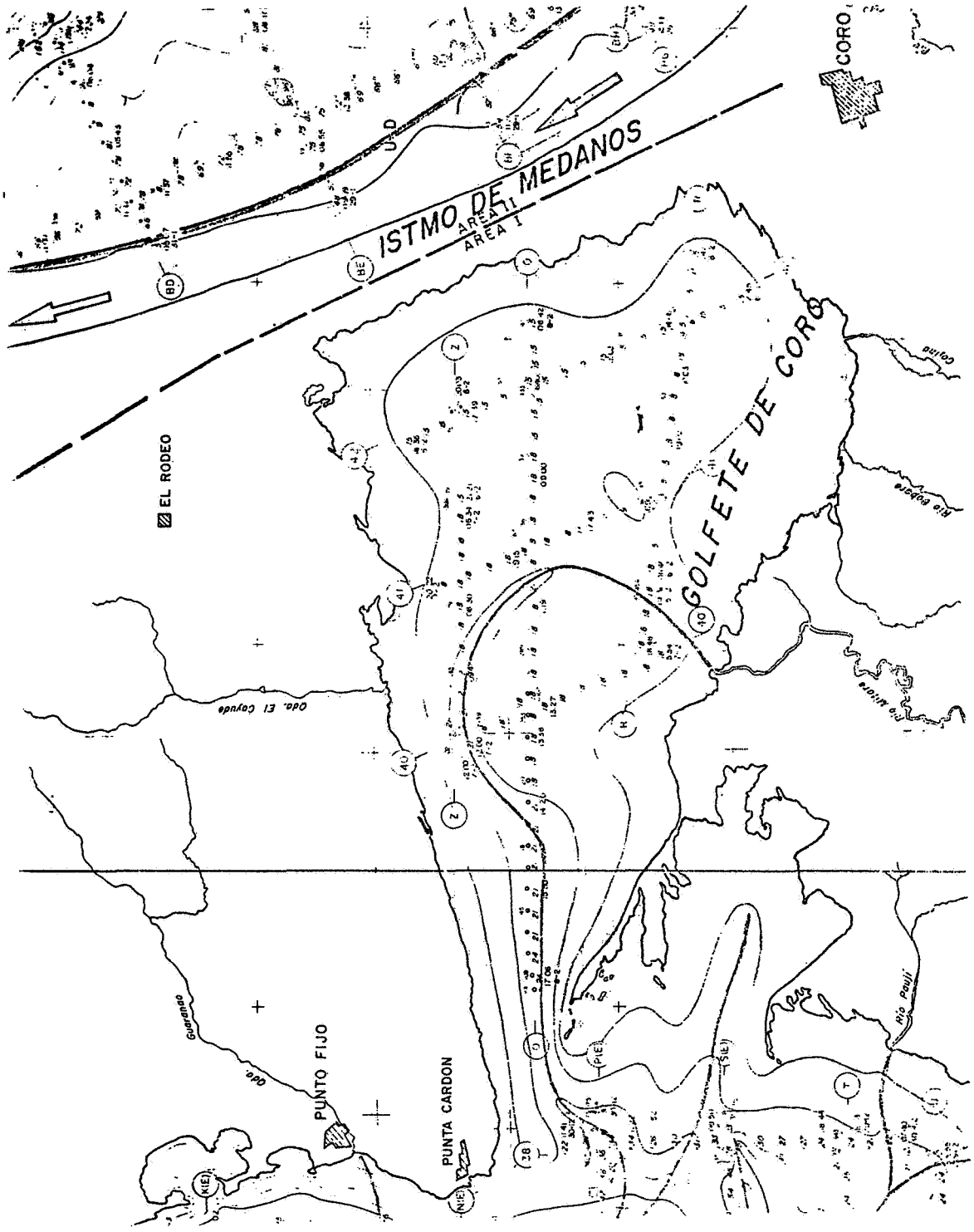
The two airports of the Península are identified by the dark gray tone of the landing strip, inside a paler gray safety belt and on a darker background of the sorrounding ground. Their trend is parallel to the directions of the prevailing wind.

The oil pipes from the state of Zulia to Paraguaná crosses the Golfete de Coro from Punta Caimán and are identifiable by their service roads.

The water pipe from the Siburúa water seeps to Paraguaná follows the Istmo de Médanos, and are identifiable by its paved road.

REFERENCE

Albrizzio Carlos, 1.969. Geomorphology of the Continental shelf of Venezuela: Goajira Península -Gulf of Venezuela - Paraguaná Península. 17 p. Texaco Report 11-173.


ISTMO DE MEDANOS
AREA I
AREA I
CORO
EL RODEO
GOLFETE DE CORO
PUNTO FIJO
PUNTA CARDON
Río Pauji

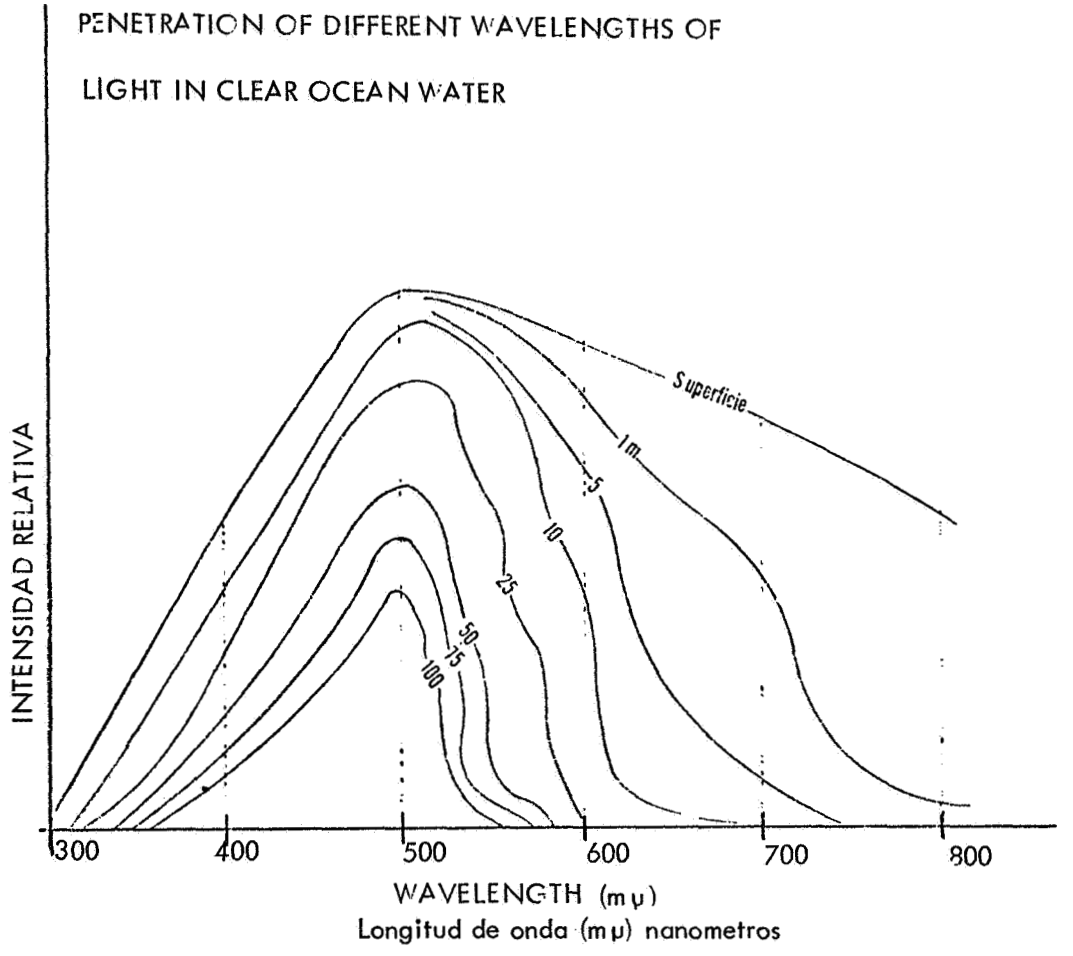


Fig. Penetración de la luz de diferentes longitudes de onda en agua clara del oceano.